# FROM WIND TO WHALES: USING AN INTEGRATED OCEAN OBSERVATION SYSTEM TO UNDERSTAND CALIFORNIA'S UPWELLING ECOSYSTEM

*A 30-month progress report submitted by the*
*Center for Integrated Marine Technologies*
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**PARTNERS:**

University of California Santa Cruz
NOAA Monterey Bay National Marine Sanctuary
Monterey Bay Aquarium Research Institute
Naval Postgraduate School
Moss Landing Marine Laboratories
NOAA National Marine Fisheries Service Southwest Fisheries Science Center
Cornell University
Jet Propulsion Laboratory

## INTRODUCTION

Both human populations and marine resources are concentrated in the coastal zones of the United States. With increasing human populations, demands on coastal resources are increasing, leading to dramatic changes in coastal ecosystems. Because we rely on the ocean for food and mineral resources as well as for recreation, it is critical that we develop conservation and management strategies that facilitate the sustainable use of marine resources while minimizing impacts on natural systems. Unfortunately, a lack of understanding of the basic processes governing coastal ocean ecosystems has been a major impediment to conserving marine ecosystems.

A comprehensive understanding of how physical ocean dynamics affect marine resources has not been realized due to 3 main limitations: 1) The development of new technologies to measure key components in the system, 2) The integration of diverse data sets across disciplines and programs, and 3) Incompatibilities in temporal and spatial resolution of data sets. Recent technological breakthroughs in numerous disciplines have made possible new syntheses, which cross traditional disciplinary boundaries. A well-integrated interdisciplinary approach offers the only prospect of truly providing predictions regarding present and future effects of human activities on marine ecosystems. We have assembled a group of physical, biological, and geochemical oceanographers; ecologists, resources managers, and remote sensing experts, together with instrumentation and networking engineers who are working *synergistically* to develop an integrated technological approach to overcome these limitations.

By creating a Center for Integrated Marine Technologies (CIMT), we are explicitly linking new technologies across disciplines of marine science to address key questions for marine resource managers – from physical forcing to fisheries and protected resources. This center provides the structure for an innovative new approach to understanding how key marine resources – fisheries, seabirds, sea turtles, and marine mammals – respond to short and long-term changes in physical oceanographic processes such as El Niño events, decadal oscillations, and long-term climate change. Such a comprehensive, integrated, interdisciplinary approach has been identified as the best approach to an integrated ocean observing system (Malone 2001). The CIMT efforts are focused on the Monterey Bay region of the Monterey Bay National Marine Sanctuary (MBNMS) – from Pt. Año Nuevo to the north to Pt. Lobos to the south out to 122°05' west longitude. This region roughly encompasses the effects of the Davenport/Año Nuevo upwelling region (Rosenfeld et al. 1994).

## GENERAL PROJECT GOALS

The Center for Integrated Marine Technologies is combining emerging technologies and data integration approaches to determine the processes underlying the dynamics of the coastal upwelling ecosystems along the California coast. Specifically, CIMT is using these technologies to investigate the critical linkages between:

- Detailed physical oceanographic measurements of upwelling intensity with
- Assessment of the availability of critical nutrients, to determine the extent to which these predict

- The distribution, abundance and species composition of phytoplankton and zooplankton, and
- The distribution, abundance and species composition of top-level consumers including fish, sea lions, seabirds, whales, and sea turtles.

This comprehensive interdisciplinary approach will serve as a model for an integrated coastal ocean observation system and establish the scientific basis for the effective monitoring and management of coastal fisheries and protected resources, especially those of the Monterey Bay National Marine Sanctuary.

## THE CALIFORNIA UPWELLING ECOSYSTEM

California's National Marine Sanctuaries (Cordell Bank, Gulf of the Farallons, Monterey Bay and Channel Islands) are situated in one of four major coastal upwelling regions worldwide. Coastal marine ecosystems are the world’s most productive - producing nearly 95% of the annual global production of marine biomass (Sherman 1991). While they represent only 0.1% of the ocean surface area, upwelling regions account for more than 21% of the world's fisheries landings (Parrish et al. 1983). In 1996, for example, the landings of commercial fisheries in the California upwelling region totaled 208,440 metric tons, with a wholesale value of $183.7 million. Despite the ecological and economic importance of coastal upwelling centers, we have only a rudimentary understanding of how coastal upwelling fuels the engines of productivity associated with them. Progress in understanding the dynamics of upwelling centers and their associated ecological communities has been hindered as workers in disparate disciplines have failed to coordinate their use of new technologies in interdisciplinary studies of upwelling processes. Understanding the strength of these linkages and the factors that contribute to their variability provides us with the foundation of knowledge needed to predict the impacts of climatic change and human activities on coastal productivity. Developing and integrating the new technologies accomplish this and will serve as a model for ocean observing in all U.S. coastal regions. Coastal upwelling occurs along the eastern margins of ocean basins as winds moving from poles toward the equator act in combination with the Coriolis force to move surface waters offshore and draw cold, deep water to the surface (reviewed by Barber and Smith 1981, McGowan et al. 1996). Upwelled water infuses surface waters with essential plant macronutrients such as nitrate, phosphate, and silicic acid, and this often leads to blooms of phytoplankton, forming the foundation of food chains that support coastal fisheries, seabirds and marine mammals. Along the California coastline, upwelling occurs during periods of strong northwesterly winds and is most intense in late spring and early summer, producing a band of cold water along the coast. This band is typically tens of km wide and separated from offshore warmer water by a series of highly variable jets, plumes and eddies (Strub et al. 1991).

## THE MONTEREY BAY UPWELLING REGION

Monterey Bay oceanography is strongly influenced by this persistent upwelling plume (Pennington and Chavez, 2000; Rosenfeld et al., 1994). During the spring and summer upwelling period, satellite imagery indicates cold surface water originates north of Monterey Bay near Davenport and appears to advect southwards across the mouth of the Monterey Bay as an upwelling plume (herein termed the Davenport Upwelling Plume [DUP] [Pennington and Chavez, 2000]). Presence of the DUP is confirmed by shipboard surveys of both temperature and salinity and direction of flow by drifter releases (Chavez et al., 1997). During active upwelling, drifters move southwards 20 cm/s. Such plumes are common features of upwelling systems, and typically appear ‘anchored' to capes, headlands, or other features of coastal topography (Strub et al., 1991). During active upwelling, surface temperature is low and nitrate high in the DUP, but chlorophyll and total production values are typically low. Biomass-specific production rates are, however, high under these conditions (Chavez, unpublished). The low production and chlorophyll values found during active upwelling are apparently due to low phytoplankton biomass of water initially upwelled near Davenport (Service et al., 1998; Kudela and Chavez, 2000). In the northeast corner of Monterey Bay, a seasonal front forms between the DUP and older, upwelled water residing in the wind shadow behind the Santa Cruz Mountains (Graham et al. 1992, Graham 1993). In this portion of Monterey Bay, chlorophyll values are often high but productivity/ biomass ratios low (Pennington and Chavez, 2000; Chavez, unpublished), suggesting residence times (2-12 d) are sufficient to allow bloom formation in this area. Southeast Monterey Bay, which is not protected from northwest wind, is likely flushed more regularly by recently upwelled water (Pennington and Chavez, 2000), though temperature and phytoplankton biomass are often higher in this area (Waidelich 1976, Schrader 1981). Much of the productivity stimulated by DUP nutrients is probably advected offshore of Monterey Bay and the continental shelves, as has been found in other upwelling areas (Chavez et al., 1991; Hutchings et al., 1995).

During fall and winter, surface currents are northward both within Monterey Bay (Breaker and Broenkow 1994) and across its mouth (Paduan and Rosenfeld 1996). At this time the DUP is absent and the spatial distributions of surface temperature, salinity, primary production and chlorophyll are more uniform relative to the upwelling season. Recent studies have demonstrated that the supply of iron, a key micronutrient necessary for plant growth, plays a critical role in controlling phytoplankton. The major source of iron to the surface waters of California is iron-rich coatings on sediments that are discharged from rivers during episodic winter storms. Paradoxically, there is a temporal mismatch between the *winter* delivery of iron-rich sediment and *spring/summer* upwelling. However, the continental shelf appears to act as a trap for the sediments delivered by winter floods. When coastal upwelling occurs in the spring, iron from the shelf sediments is entrained in upwelled water along with elevated concentrations of nitrate and silicic acid. Southerly currents result in the enormous productivity of this region being swept into Monterey Bay (Kudela and Dugdale 2000, Kudela and Chavez 2002).

## CLIMATIC IMPACTS ON UPWELLING CENTERS

Adding further complexity to coastal productivity are the influences of climatic events occurring interannually (El Niño/La Niña) and interdecadally (climatic regime shifts). Declines in upwelling, potentially linked to human activities, led to changes in productivity along the West Coast of North America beginning in 1977 (McGowan et al. 1998). However, a strong reversal, associated with multidecadal changes, occurred in the late 1990s (Chavez et al., 2003), making it clear that we need to understand the natural system before we can assess human impacts. Unfortunately, our ability to predict the potential impacts of these events is poor. For example, during the 1997/98 El Niño event, productivity was generally low in the Eastern Pacific. However, weak upwelling very close to the central California coastline fueled moderate levels of primary production (Kudela and Chavez 2000 & 2002, Chavez et al. 2002). Seabirds and marine mammals that normally range far offshore responded to this climate-induced inshore shift in productivity and were concentrated in very nearshore waters (Benson et al. 2002). In contrast, other animals that rely on the productivity of upwelling centers, such as squid, experienced dramatic declines and fishery collapse. Combined, these new insights indicate phytoplankton production and the distribution and abundance of animals from zooplankton to fish, squid, seabirds and whales may be determined by complex interactions among climatic events, riverine input of iron, and wind-driven coastal upwelling of nutrients.

## INTEGRATION OF NEW AND EXISTING TECHNOLOGIES

The CIMT has initiated a new approach to interdisciplinary coastal research by simultaneously collecting and integrating data collected via remote sensing, coastal observation moorings, shipboard surveys, and apex predator tagging and tracking. By utilizing technology on these different platforms, we can examine temporal changes in the Monterey Bay coastal environment using (mooring-based measurements) within local (ship-based measurements) and regional (satellite-based measurements). Individually, each component measures physical, biological and chemical components of coastal processes at specific temporal and spatial scales. Integrated together, they provide the data to develop predictive models across multiple spatial and temporal scales of how marine resources respond to variability in coastal dynamics. CIMT is integrating the measurement of a range of key parameters for understanding coastal dynamics.

A board of directors runs the Center for Integrated Technologies. This board is comprised of one representative from each of the following groups:

| | | |
|---|---|---|
| *Ship Survey* | *Dr. Don Croll* | *UCSC* |
| *Remote Sensing and Modeling* | *Dr. Raphe Kudela* | *UCSC* |
| *Database and Visualization* | *Dr. Margaret McManus* | *UCSC* |
| *HF Radar* | *Dr. Jeff Paduan* | *NPS* |
| *Mooring* | *Dr. Francisco Chavez* | *MBARI* |
| *Outreach* | *Dr. Steve Lonhart* | *MBNMS* |

Dr. Gary Griggs, Director of the Institute of Marine Sciences, oversees the board as the chairman. This structure has been extremely successful in bringing together inputs across a range of disciplines from several different institutions. A detailed 30-month progress report for each of these groups is provided in the following pages. Please note that the Outreach group is new as of year 2.

## SHIP SURVEY GROUP

### Progress to Date

The research groups of the shipboard survey effort are involved in shipboard observations of the regional physical, chemical and biological data collection on a series of transect lines shown in Figure 1. They are also involved or interested in the data produced on the two new moorings that will be placed in the region in the future (Figure 1), and in satellite imagery of sea surface temperature and sea surface chlorophyll. During year two, we successfully completed all nine scheduled surveys (August-November 2003, January & March 2004, and May –July 2004. In addition we completed the August 2004 survey as part of year 3's scheduled sampling activities.

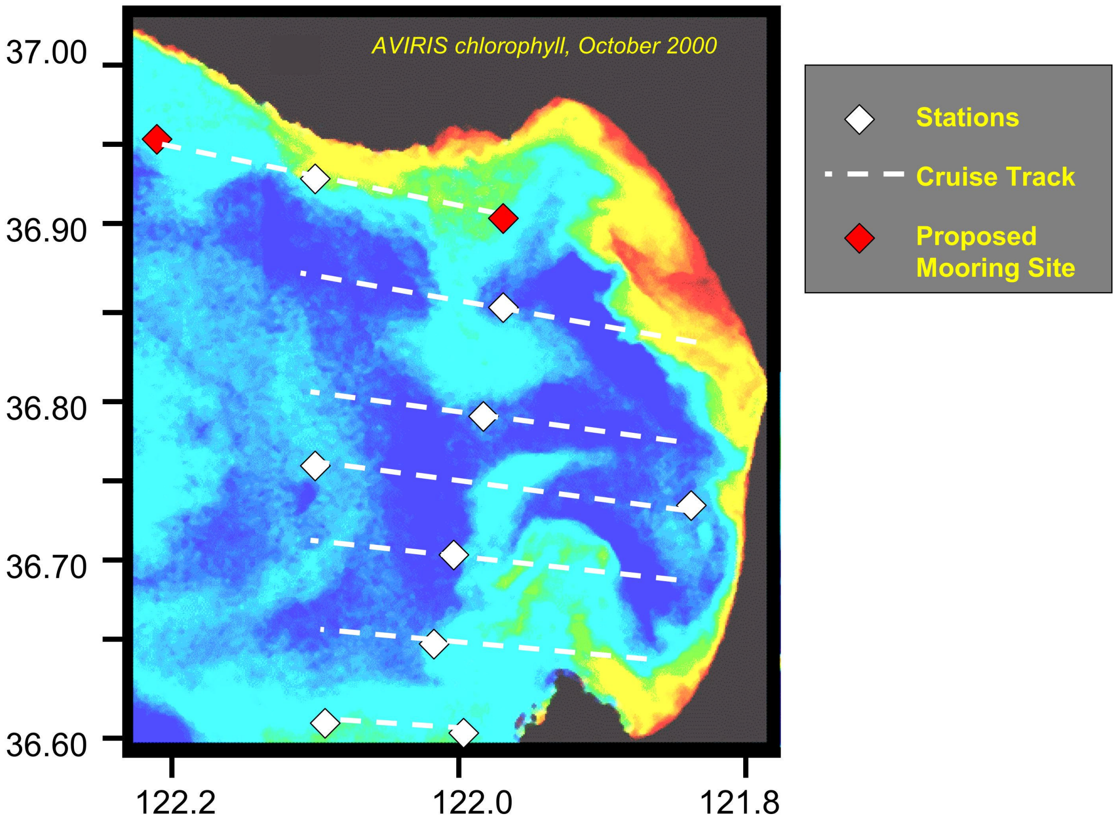



Figure 1. Monterey Bay Wind to Whales transect lines and proposed mooring sites

**Shipboard Survey Data**

The ship survey component collects information on the following parameters during oceanographic cruises that take place approximately monthly within Monterey Bay:

- Sea surface temperature
- Water temperature with depth
- Macronutrient distribution and abundance
- Micronutrient distribution and abundance
- Sea surface chlorophyll
- Sea surface and profiled optical properties
- Phytoplankton community structure
- Zooplankton abundance and distribution
- Zooplankton community structure

- Schooling fish distribution and relative abundance
- Seabird distribution and abundance
- Marine mammal distribution and abundance
- Sea turtle distribution and abundance

Specific year 3milestones with respect to these components include:

*Underway measurement of Sea Surface Temperature* – The Seabird SBE-45 flow-through SST system and complimentary Turner Designs SCUFA fluorometer/turbidity meter continues to function normally.

*Underway measurement of surface/subsurface currents*. – The RDI WorkHorse 300 kHz ADCP that was mounted on the Research Vessel John Martin in year two has undergone extensive reprogramming to allow it to function simultaneously with the EK-60 hydroacoustic system. Basically this entailed realigning the circuitry to enable it to be triggered by the EK-60 system. These modifications were complex and extensive and involved both technical staff associated with this project as well as at RDI. The system was completed in December and successfully deployed during the January 2005 survey.

*Conductivity, Temperature, Depth, Fluorescence at transect stations* – The Seabird SBE-19, continues to function normally. In December 2004, the Wetstar fluorometer was serviced and is now functioning properly. Currently we are in the process of reprocessing all archived CTD data to remove data associated with pre-cast soak time for the instrument after standard QA/QC protocols determined that these data had not been removed during the processing phase.

*Micronutrients at the transect stations*. – The system to collect samples for dissolved and particulate iron and manganese at each of the transect stations that was developed and installed last year continues to function normally. A third individual has been trained in ultra-sterile sample collection protocols in order to add flexibility to sampling activity. The sampling apparatus was damaged during the January 2005 cruise, but should be functional again for the scheduled March 2005 cruise.

*Size fractionated chlorophyll at the transect stations* - Sampling continues to include > 10, >1, and > 0.45 micron fractions. To date all samples have been processed.

*Discrete bottle measurements* – All samples for total suspended solids, biogenic and lithogenic silica, as well as CHN (particle composition) have been preprocessed for final analysis. Most of the CHN samples (through November 2004) have been analyzed. CDOM absorption spectra (phytoplankton and detritus) have all been completed. These measurements are complementary to the long-term database maintained at MBARI and provide a suite of samples for future modeling efforts. Representative samples continue to be collected for HPLC pigments and flow cytometry, but are not currently being analyzed routinely. Total suspended solids (TSS) analyses have been completed for all samples collected to date.

*Semi-quantitative microscopic identification of the entire phytoplankton community* - Sampling protocols have been developed and the system has been operational since November 2002. Currently all samples collected through January 2005 have been processed.

*Quantitative diagnosis of toxic phytoplankton species using molecular probes.* – Sampling protocols have been developed and the system has been operational since November 2002. All samples through January 2005 have been processed.

*Measurements of domoic acid.* – All samples collected since November 2002 have been processed at an analytical facility located at UCSC.

*Underway sampling of zooplankton backscatter* –the EAK-60 split beam echosounder system continues to sucessfuly operate at all three frequencies. Acoustic backscatter data has been collected for all cruises through January 2005. Zooplankton backscatter data have been filtered and scrutinized for both total zooplankton backscatter and krill backscatter through the November 2005 survey.

*Zooplankton net sampling* - A total of 57 net samples have been collected since August 2004. All samples have been processed for biovolume and have been characterized for general zooplankton community structure as well as krill species composition and population demographics.

*Marine mammal and seabird distribution and abundance* – Data has been collected through January 2005 using standard National Marine Fisheries Service techniques. In addition data through November 2004 have been processed.

*Toxic algal species* - For the first time, The CIMT shipboard collections have allowed us to see the offshore patterns of toxic algal species in the Monterey Bay region. The CIMT survey data show that species producing 3 major toxin suites are present at occasionally dangerous levels offshore, species previously known mostly from data obtained at shore stations: domoic acid (DA) from diatoms (from 2 *Pseudo-nitzschia* species), saxitoxin (STX) from a dinoflagellate (*Alexandrium catenella*) and a suite of dinophysotoxin/pectenotoxins from dinoflagellates (from several *Dinophysis* species). For comparison, time series data from another study (Silver's) also are available for the toxins at the Santa Cruz Wharf, A comparison of the CIMT and wharf data sets show that the nearshore (wharf) data appear largely inadequate for assessing offshore wildlife dangers from algal toxins. In Monterey Bay, DA is known to contaminate pelagic food webs from zooplankton (e.g. krill: Bargu et al 2002) to apex predators, including seals and whales (Scholin et al., 2000; Lefebvre et al., 2002), and STX also has been found at high levels offshore in sardines (Antrobus et al. 2003). Blooms of toxic *Pseudo-nitzschia*, with cell numbers sufficient to produce unacceptable DA concentrations in shellfish (i.e. $5 \times 10^4$ cells/l), have occurred 4 times during the 2 year CIMT surveys. Figure 2 shows one of the blooms encountered on a CIMT survey cruise.

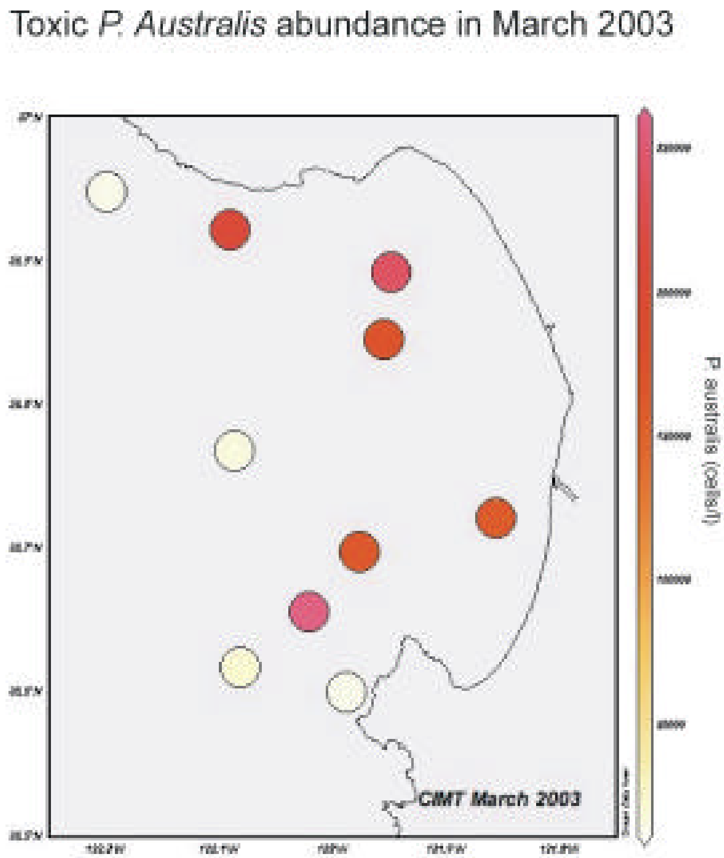



Figure 2. Results from the CIMT harmful algae monitoring shipboard component during a large *Pseudo-nitzschia* bloom in March 2003. Samples are processed using a species-specific molecular probe (whole-cell format) and directly counted using epifluorescence

Interestingly, CIMT data for the canyon station (T401), combined with a local, longer-running dataset obtained at this same site (M1, a MBARI station- data from M. Silver), suggest that the abundance of DA-producers may be declining, whereas the numbers of the STX-producers are increasing, possibly reflecting a regime shift, Figure 3. Should *Alexandrium* continue this upward trend, the pelagic food webs of the bay may encounter even more dangerous exposures to algal toxins in the future, as STX is a much more potent toxin than DA, and likely will be distributed by the animal species presently vectoring DA (e.g. planktivorous fish). The CIMT data set also indicates that there is no predictable offshore center for toxic population, but strongly suggests that the most toxic DA populations (i.e. cells containing the highest DA levels) occur in waters over the submarine canyon, a key foraging site for cetaceans and marine birds.

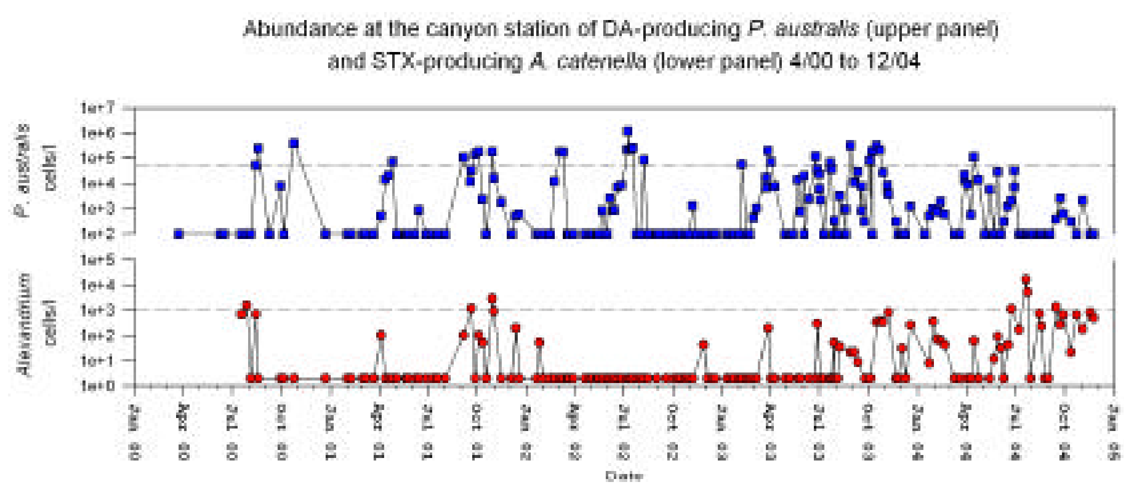



Figure 3. Time-series of cell abundance in Monterey Bay of DA-producing *P. australis* (upper panel) and STX-producing *A. catenella* (lower panel) between April 2000 and October 2004.

The rise of abundance of a locally new dinoflagellate, *Cochlodinium*, most likely *C. catenatum*, is clearly documented in the 2004-2005 CIMT data, Figure 4. In the bay, the species caused "brown tides" during the year and cell numbers sometimes exceeded $5 \times 10^4$ $L^{-1}$, a minimal estimate because many cells ruptured when preserved for cell counts. In areas where cells were very abundant, the waters were slimy and mussel deaths were noted on the coast. In waters of Guatemala and Costa Rica, where blooms of the species occurred in the 1980s, the slime was associated with fish and coral deaths. The species is known from Mexico, Guatemala and Puerto Rico, with blooms increasingly reported in Mexico. A closely related congener , *C. polykrikoides*, is causing deaths of farmed salmon in Vancouver, B.C and serious economic losses. Almost no work appears to have been done on the fish-killing agents of *C. catenatum*, and even the species designation is uncertain, with the genus clearly needing taxonomic revision to show the affinities of the various noxious species, whose occurrences are increasing worldwide.

Figure 4. New dinoflagellate, *Cochlodinium*, most likely *C. catenatum*

## REMOTE SENSING AND MODELING GROUP

CIMT Remote Sensing activities focus on providing data from satellite, airborne, shore-based, and autonomous sources, including marine mammal tagging, and, through collaboration with other programs (e.g. MBARI; NSF-funded projects such as CoOP WEST and RISE), AUVs and towed vehicles. The goal of the remote sensing group is to characterize the large-scale environment in which both the CIMT program and the MBNMS are embedded. This includes characterization of physical features (~1 km resolution) such as the presence/absence of frontal fields, and the spatial/temporal coupling of physical and biological properties. These data are provided to other groups, particularly the shipboard component, for integration into their products. In addition, they are used separately for regionally tuned models to estimate primary production and new primary production (e.g. export production). The Remote Sensing Group also participates in the Shipboard operations as both an end-user for calibration/validation of the remotely sensed data, and as an operator of some of the core instrumentation, which is covered elsewhere in the proposal. With the development of an enhanced modeling component in Year 3 of CIMT (with planned expansion in Years 4-6), we anticipate working closely with that group to provide model input and validation.

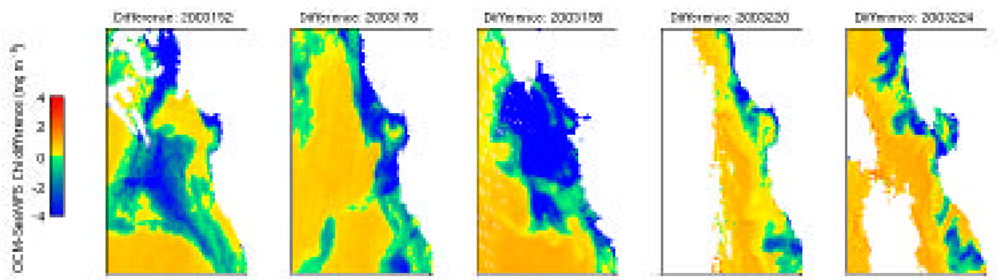
The remote sensing component may be described in three sections:

- Operational satellite products closely linked to national programs
- Regional efforts including airborne overflights, shore-based HF radar systems, and in situ ground-truthing activities

- Developmental efforts including marine mammal tagging

**Operational satellite products**

A core component of any existing or future Ocean Observing System (OOS) structure is the development of “backbone” components such as remote sensing. The CIMT program has been maintaining and processing satellite data regionally. The Monterey Bay Aquarium Research Institute (MBARI) was the real-time license holder for capture of HRPT images from the SeaWiFS satellite on the west coast. AVHRR data are available from the west coast CoastWatch node, which recently relocated to the Pacific Fisheries Environmental Lab. MODIS data are available via the Goddard DAAC, as well as from Oregon State University. In collaboration with Dave Foley (CoastWatch) and the Sea Space Corporation, we have also been evaluating near real time data from the Indian Ocean Satellite (OCM), which has 300-meter resolution data similar to SeaWiFS and MODIS ocean color (Figure 5).



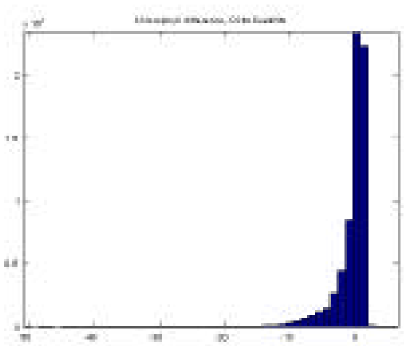


Figure 5 Comparison of OCM-derived chlorophyll versus SeaWiFS OC4v4 chlorophyll for several days in 2003. The upper panels represent the difference (OCM-SeaWiFS); the panel at left shows the histrogram for all match-ups. Although OCM has better spatial resolution, there is a non-random bias in the chlorophyll products. We are currently working with PFEL and SeaSpace to develop a better product for OCM.

*Accomplishments*: During the first two and a half years of this project, we have focused on disseminating the remote sensing products by setting up an automated processing and archiving facility, and we currently make products available in near-real time at the CIMT Remote Sensing web page, http://oceandatacenter.ucsc.edu.  In preparation for the development of a National OOS, we have been working on reducing the redundancies associated with these efforts; for example, both we and PFEL archive and disseminate ocean color and temperature data, and all of these data are also available from national archives such as the SAA (NOAA) and the Goddard DAAC (NASA). Beginning in year 2 and as a core proposed activity for year 3, we established collaborations with several of these groups to set up a virtual distributed network which will streamline the processing and archiving of these data. Partners include:

- *NOAA*: NOAA has tasked Dr. Richard Stumpf with archiving and distributing ocean color data for the US coast, and the National Sanctuary programs. We serve as a regional data portal for NOAA-processed ocean color products (radiance fields, chlorophyll, statistical products such as annual means). A spinoff project related to CIMT was recently funded by the NOAA MERHAB program, and this includes development and validation of remote sensing products for the California Department of Health Services harmful algae monitoring.
- *PFEL/CoastWatch/Sea Space*: Dave Foley has been providing us with both AVHRR and OCM data. CIMT has been working with Foley and Yi Chao (JPL) to interpret these data with the goal of incorporating these data into our virtual distribution system, and into the modeling effort. As part of this, CIMT is validating a CLAVR-X cloud mask scheme for central California, which will be institutionalized by Foley for CoastWatch.
- *NASA*: In anticipation of the end of SeaWiFS, we have transitioned in Year 3 to fully supporting near-real time MODIS Aqua data.
- *UCSC*: We have continued to archive and disseminate data, and have developed several new products based on end user requests, such as weekly composites centered on each cruise period (Figure 6).

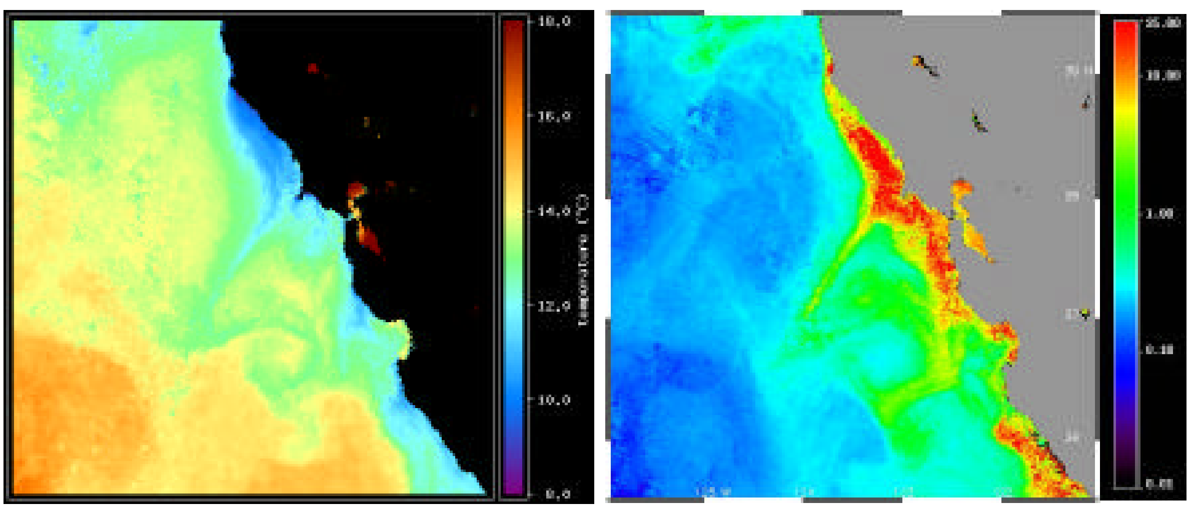



Figure 6. An example of the 8-day median images for SST (left) and chlorophyll (right) produced for each cruise period (these images are from May 2004). The website also contains animations of all the imagery that went into each composite. Data are available to CIMT investigators in several formats

(http://es.ucsc.edu/CIMT/CIMT%20Data%20Products.html)

Moving forward, our primary goal is to continue our successful collaborations with our national backbone partners and ensure continued access to the remote sensing data by CIMT partners and

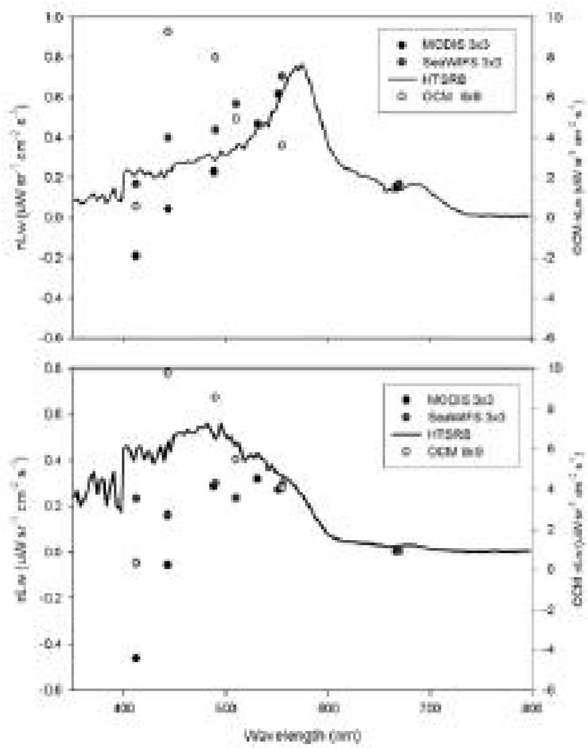



Figure 7. A comparison of MODIS, SeaWiFS, OCM, and in situ data collected with a Satlantic HyperPro II sensor at M0 and M1 moorings in Monterey Bay, California. Both MODIS and OCM exhibit substantial over-correction of the atmosphere, resulting in low/negative water leaving radiances in the blue region of the spectrum. This particular data set (October 2003) was from a red tide event in Monterey Bay.

end users. This is especially critical now that SeaWiFS has ended and MODIS (as well as other sensors) are available. One important task which we have already begun, is to compare the various data sets (SeaWiFS, MODIS, OCM, AVHRR, GOES, etc.). We have identified significant differences between sensors (Figure 7), and are working on developing a standardized data product or products to minimize differences. We are also working directly with PFEL (Foley) to ensure that there is a standardized SST product based on the new NOAA HDF file format (previously CoastWatch was using the cwf format) and the CLAVR-X cloud mask options. We are also working closely with Yi Chao (Modeling) to integrate our products with the model output.

**Regional efforts**

During 2003, we collected a total of 40 hyperspectral (ocean color) airborne maps of the Monterey Bay (e.g., Figure 8). The sequence of simultaneous temperature and color maps provide the context for in-water CIMT surveys. Survey results are available on line at: http://www.oc.nps. navy.mil/~teanders. We have also coordinated with CI-CORE to fully utilize the PHILLS2 hyperspectral data. In collaboration with Dr. John Ryan (MBARI), we have also been using AVIRIS overflight data when available (Ryan et al., submitted). While these efforts are not part of an "operational" framework, they are extremely valuable for testing and refining data products. For the second half of Year 3, we have continued to work with these high resolution data sets as an exploratory tool for optimizing the lower resolution satellite products (e.g. Figure 7).

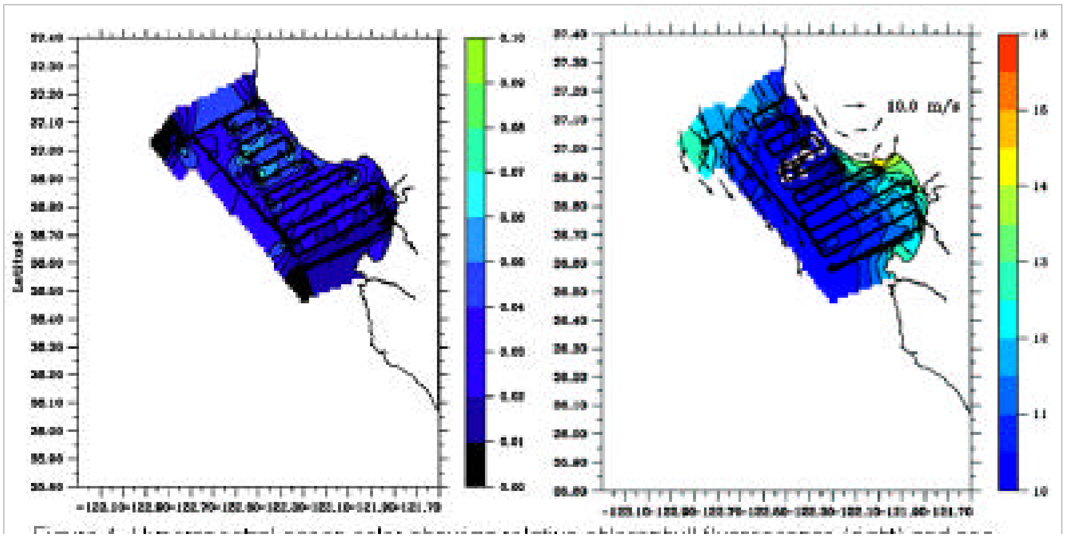


Figure 8. Hyperspectaal ocean color showing relative chlorophyll fluorescence (right) and sea surfa
temperature overlayed with wind speed (left) from an airborne overflight on May 27 2003.

Kudela is also participating in the NOAA COAST workshops, being held in anticipation of future ocean color sensors on the GOES platforms. If successful, CIMT will be well positioned to take advantage of that operational product, since we already have the airborne and in situ data to assess the utility of the high spatial resolution (ca. 450 m) and temporal coverage (several times per day) of the planned GOES ocean color system.

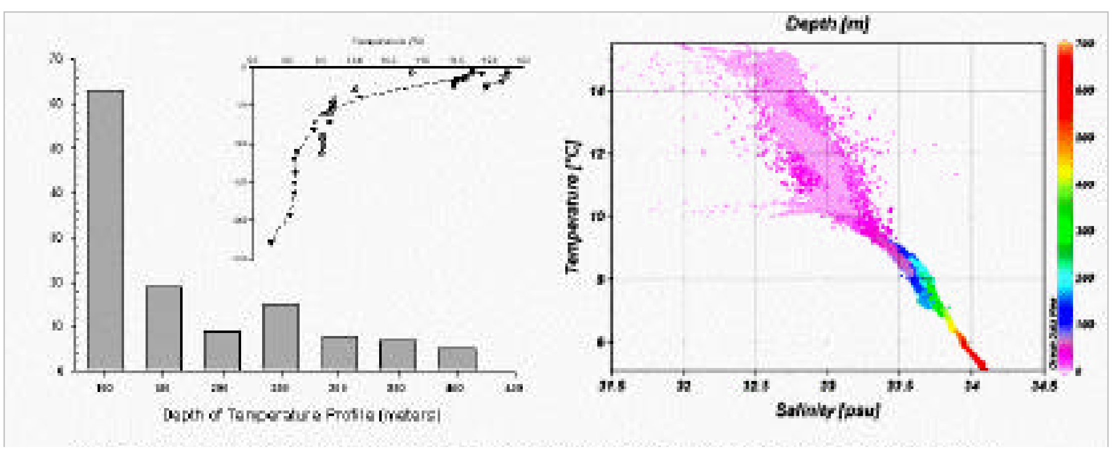


Figure 9. Depth histogram plot (left) for the first 4 SRDL temperature tags deployed on California sea lions. The inset shows 4 representative profiles. Right: Temperature, Salinity, Depth plot from the new CTD tag deployed on a northern elephant seal in Monterey Bay.

Although covered in greater detail in the shipboard section, we have also instrumented the *R/V John Martin* with an underway fluorometer (Figure 10), and a passive 7-channel radiometer package and active 2-channel backscatter instrument to the CTD profiler for verification of the satellite and airborne data. We also purchased a Satlantic HyperPro II system (identical to systems at MBARI and CICORE; Figure 7) for use in ground truthing and product development. We are working closely with our regional partners to develop standard data collection procedures, and participate in interoperational activities such as the PHILLS 2 overflights sponsored by CICORE.

During Year 3, we have successfully merged the underway shipboard data collection with the JPL database and modeling efforts. As the modeling progresses, and especially if a biological component is added, we anticipate providing validation and potentially data for assimilation into that component of the model.

**Developmental efforts**

An important value-added contribution from CIMT is the development and validation of regional or experimental data sets. There are numerous non-standard (or research) products available from remote sensing that are not routinely disseminated to the public.

For Year 3, we explored the applicability of some novel products and sensors, including the use of the 250 mm (terrestrial) bands on MODIS for mapping near-shore sediments, functional group identification of phytoplankton assemblages (e.g. diatoms vs. dinoflagellates) from hyperspectral data (Dierssen et al., submitted), and correlative relationships between remotely sensed backscatter, chlorophyll, and bio-available iron (Kudela et al., submitted). The availability of frequent cruises and ancillary ground-truth data make this CIMT project an ideal venue for such development.

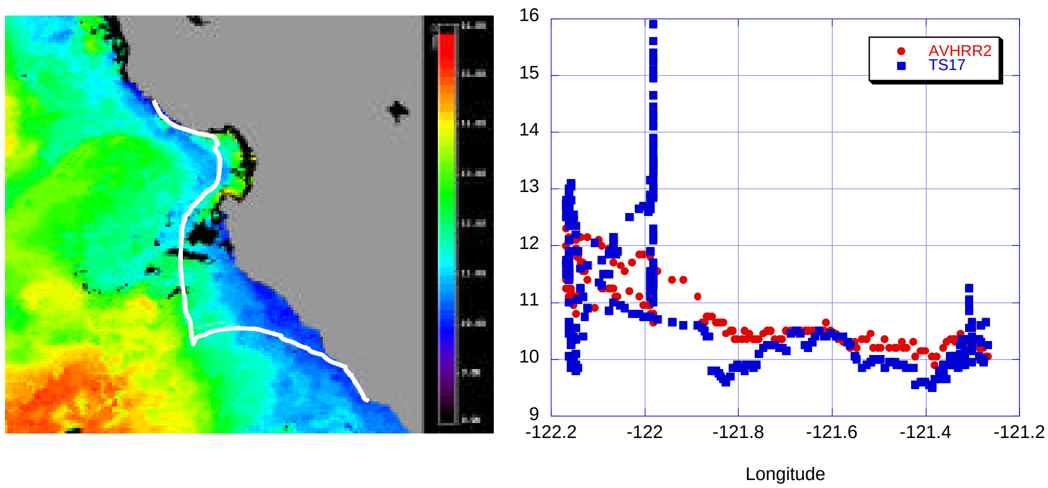



Figure 10. A comparison of SST from AVHRR and the CIMT data loggers on Northern Elephant Seals (left; AVHRR image with seal track line). The Right panel shows the SST derived from the tags (blue) versus satellite (red), showing an excellent correspondence, as well as distinct thermal fronts which don't appear in the satellite data. The tag data are already being incorporated into the JPL modeling effort.

On the hardware side, we continued our work with the marine mammal group to evaluate the use of tags on California sea lions, similar to the much larger scale work that has been done with elephant seals (Boehlert et al., 2001). An example of temperature profile and the depth range are provided in Figure 9; these data are already being incorporated into the model database, and are also being used to compare with remotely sensed data (Figure 10). We have also extended the use of sea lions as sensing platforms with the deployment of archival light-sensing tags on 8 California sea lions. These data could provide another high-resolution, 2-D dataset of water quality and chlorophyll biomass (using attenuation as a proxy). While highly exploratory, funding for this component is provided from other sources (ONR, Packard Foundation, and a pending NASA proposal).

**Modeling**

Beginning with Year 3 funding, the modeling group has aggressively pursued several areas critical to CIMT's mission. We have adapted and enhanced a regional circulation model for Monterey Bay to the greater CIMT region.CIMT data has been incorporated into a database for use with the model/data assimilation system. And we have synthesized CIMT shipboard data for model/data comparison. With these capabilities in hand, we are now beginning a 1-year data assimilative hindcast of the Monterey Bay circulation based on CIMT data, exploring the dynamics of the circulation, with an emphasis toward the connection between the physical forcing fields and the nutrient supply, and preparing for a near-real-time data assimilative forecasting system.

During year 3, we have adapted the physical ocean model developed by the NOPP-funded SCOPE and ONR-funded AOSN II for the use of CIMT. The ocean circulation model is based on the Regional Ocean Modeling System (ROMS). The CIMT ROMS assimilation system consists of three nested domains: a 15-km resolution model over the entire U.S. West Coast, a 5-km resolution domain over the central California, and a 1.5-km domain around the Monterey Bay. The finer resolution ocean model is forced by the 3-km surface wind produced by the Navy's Coupled Ocean-Atmosphere Mesoscale Prediction System (COAMPS), while the coarser resolution ocean model is forced by the blended COAMPS/QuikSCAT wind product as described in Chao et al. (2003). The three models are run in a triply-nested manner exchanging boundary conditions at every time step of the larger domain. A 3-D variational (3DVAR) data assimilation scheme is implemented in order to assimilate all temperature and salinity data collected by CIMT. The CIMT ROMS configuration improves the previous AOSN ROMS configuration with more vertical layers, realistic bottom topography, and a reduction of minimal water depth from 50 m to 10 m. This is essential for the CIMT application because of the extensive data collected on the Monterey Bay shelf. The objective of the CIMT year 3 assimilative modeling effort is to produce a 1-year hindcast during August 2003 to September 2004. Among the more exciting developments of the modeling component is the integration of the CIMT sea-lion data into the assimilation system. We believe this is the first such effort of this kind.

The modeling group has also begun a synthesis of collected physical data in an effort to characterize and interpret the physical circulation during periods of interesting CIMT collections. We have analyzed the relative strength of upwelling and duration of relaxation based on local wind records, and are comparing remotely sensed information with in situ hydrographic data during the cruise periods. The synthesis of these data along with the collected biological and chemical data has driven the development of a forward modeling capability, similar to the assimilation system, to explore biological and physical processes within Monterey Bay. We are investigating the effect of changing wind stress conditions on the pathways and time-scales of upwelling using this model.

## DATABASE GROUP

### Introduction

The goal of the database group is to develop a distributed data and software architecture to locate, retrieve, and utilize information collected in the coastal ocean environment. Since collected data sets seldom contain descriptive information regarding the nature in which they are collected, additional information in the form of metadata is required. CIMT has developed a web-based tool to simplify and verify the integrity of metadata records. In order to best use metadata records for searching across distributed systems, commonly accepted vocabulary are employed to ensure unambiguous data set identification.

### **The CIMT database**:

*Database:* Since the completion of the Relational Database Management System (RDBMS) structure in March 2004, the database coordinator has met with individual PIs to obtain sample datasets in order to modify the database and create parsers to allow data technicians to upload data into the database. Six parsers have been written to upload CTD, Echosounder, Zooplankton, Chlorophyll, Nutrients and Micro Nutrient data into the database.

*Standards followed:* The system is designed with the foresight in establishing a network of regional coastal observing centers. As such, several standards and protocols are followed to ensure integration of regional data holdings. The primary standard followed is the Federal Geographic Data Committee (FGDC) Standards Reference Model for metadata entities. Keyword or phrases that describe a data set are standardized using the NASA Global Change Master Directory (GCMD) keyword list for earth sciences. The naming of measured variables and methods of measurement are standardized by augmenting a combination of GLOBEC and JGOFS parameter lists. The combination of these documents reduces the ambiguity of data searches, ensuring through searches across regional data centers. All metadata, describing data entered into the database, are FGDC compliant. Each individual entering data is assigned a unique identification number. All data sets submitted by that person are then referenced by that identification number. In doing this, all data sets become searchable by the submitter. The visualization and download application recommended by IOOS is the Live Access Server developed by NOAA PMEL.

### Uploading and Downloading Data:

This system may be described in three sections:

*1) Content Management System (CMS)*: The purpose of using a CMS is to organize documents. It stores content such as documents, shipboard data and metadata in a database, and displays to the user whatever he or she requests. An easy-to-use interface allows data providers to add, remove, or modify content. The ability of this tool addresses the need to provide information to an array of users with varying interests in a timely manner. Content may be submitted to the CIMT web page. Types of content include status reports of upcoming cruises and post-cruise summaries, and public alerts to events, which may be of interest in the region, such as public health issues and recreational water use advisories.

*2) Data organization and submission:* Submission of collected data sets are via HTTP and stored in RDBMS tables optimized for each type of collected data. The CMS is the web interface designed for individuals to submit data sets to the RDBMS.

Submission of data is performed in three parts:

1. The submitter (data technician or PI) logs on the system (CMS) through the cimt.ucsc.edu website.
2. The submitter is associated with one or several parsers depending on his/her level of responsibility within CIMT. The submitter chooses the type of data to be entered, and submits the data to the database.
3. The data is then transferred through the network to the server where it undergoes an automatic duplicate check with the existing data in the database to assure that data is not entered twice.

*3) Data dissemination**:*** The method of retrieving data currently used is the Live Access Server (LAS). The intended purpose of LAS is to aggregate and visualize globally gridded data sets. In the future, in order to meet the needs of CIMT, a new 'front-end' is necessary to provide improved functionality. CIMT is approaching this by utilizing a spatial mapping program, Map Server, to illustrate station locations, mooring locations, synoptic coverage, transects in the context of overall water depth, distance from shore, pre-defined sub-regions, i.e. Santa Cruz and Monterey Bights, Monterey Bay Canyon, and shelf areas. Querying stations or regions trigger the temporal scope of the data set as well as information on sensors used and related measurements, i.e. temperature is intimately related to salinity, CTD measurements are related to flow-through measurements.

In December 2004, an end-to-end package (CMS e107 – Database – Live Access Server) was completed for the CTD data:

1. The Content Management System (e107) was modified with the addition of a CTD parser to allow the upload of CTD data into the database.
2. The database was modified to take into account specific CTD variables into the CTD table.
3) The Live Access Server (IOOS recommendation) was customized to allow users to visualize and query the CTD data in different ways such as direct NetCDF downloads and quick plots. A new query operator was introduced where users can select one station at a time.

In January 2005, an end-to-end package (CMS e107 – Database – Live Access Server) was completed for the echosounder data.

1. The Content Management System (e107) was modified with the addition of an echosounder parser to allow the upload of 3 different frequencies of echosounder data (38, 120, and 200 kHz) into the database. Due to the large amount of data being uploaded, the echosounder parser was designed to optimize performance in data transfer and data entry into the database.
2) The database was modified to take into account specific echosounder variables into the three echosounder frequency tables. The design of the database was modified to allow better performance during the duplicate check performed right before the data is inserted into the database.
3) The Live Access Server (IOOS recommendation) was customized to allow users to visualize and query the three echosounder frequencies data in different ways such as direct NetCDF downloads and quick plots. A new query operator was introduced where users can select one transect at a time.

In the next couple months, complete end-to-end packages will be operational for the remaining 4 datasets: Zooplankton (Feb 18$^{th}$), Chlorophyll (March 4$^{th}$), Nutrients (March 18$^{th}$) and Micro Nutrients (April 1$^{st}$).

**IOOS (Integrated Ocean Observing Systems) Interoperability:**

Since the NOAA IOOS Interoperability Demonstration, CIMT continues to participate in the testing and provide near real time (within a 1-2 h window) measurements of ocean surface temperatures to the Open GIS Consortium (OGC) publisher developed by DMSolutions (IOOS partner). The product created from this demonstration is a web-accessible map depicting locations of measurements and the most recent values at those locations (http://dev1.dmsolutions.ca/ioos2/). The interoperability demonstration is summarized in the 18-month progress report (UCSC, 2004).

In order to continue the interoperability effort initialized by NOAA IOOS, the Center of Northern California Ocean Observing System (CeNCOOS) has created a Data Management and Communication Committee (DMAC). The first objective of DMAC is to create a pilot project with the specific goal of demonstrating early interoperability among CeNCOOS partners.

## SHORE-BASED MEASUREMENTS OF SURFACE CURRENTS (HF RADAR)

The high frequency (HF) radar program of CIMT is expanding observing system capabilities in two areas: 1) improving real-time surface current coverage, reliability, and user products and 2) developing new mapping options for over water winds and waves using multi-frequency HF radar systems. In the case of surface current maps, CIMT is working closely with California's new Coastal Ocean Currents Monitoring Program (COCMP) to produce continuous maps for the region around central California. CIMT investigators were also involved with planning efforts at the national level to extend the prototype surface current mapping systems to all of the nation's coastlines (Paduan et al., 2004).

Two types of HF radar systems, the commercially available CODAR/SeaSonde and the UCSC Multi-frequency Coastal Radar (MCR) systems, contribute to the real-time surface current maps in the CIMT region.  UCSC also recently procured two advanced CODAR systems using Navy funding each of which can operate simultaneously on two different frequencies.  A major goal of the CIMT development program is to transition multi-frequency based algorithms for over water winds and waves from the four-frequency MCR units to combinations of dual-frequency, commercially available CODAR units.  During this period, the first dual-frequency CODAR system was installed in Moss Landing freeing up the existing single-frequency unit to be used to expand overall velocity mapping to the area north of Santa Cruz.

In terms of personnel, the HF radar program has been reorganized during this reporting period into three groups: 1) UCSC technicians funded under COCMP who will be responsible for maintaining all of the real-time systems and ensuring continuous surface current mapping data, 2) researchers at NPS working under CIMT who will continue to focus on improving the real-time algorithms for surface current mapping and on creating new user products, such as short-term transport forecasts and long-term transport statistics, and 3) researchers at UCSC working under CIMT who will continue to focus on testing new algorithms for mapping over water winds and surface waves based on the additional information available from multi-frequency HF radar systems.  They are also working to improve HF radar estimates of surface currents by detecting erroneous current vectors and editing out or correcting them.

In terms of hardware, a specific implementation plan was developed during this period to utilize the unique range of instrumentation available under CIMT.  The new dual-frequency CODAR system at Moss Landing will be paired with a second dual-frequency system at Santa Cruz, which will also free up the existing single-frequency unit in Santa Cruz to be used to expand the overall velocity mapping area.  MCR units will be operated next to the dual-frequency CODAR units.  The Santa Cruz MCR system is in place today and a second system will be installed in Moss Landing very soon.  The experimental MCR units have the advantage of simultaneous operations on four frequencies.  However, in that mode, they do not have sufficient signal-to-noise performance to be used as wide-area mapping systems.  The new configuration will allow for three-frequency operation by combining results from dual-frequency CODAR units with MCR units operated on one frequency for better dynamic range.  At the same time, wave mapping software, which requires longer, real-aperture arrays like those of the MCR units, will be tested with the better-performing, single frequency MCR units.

Throughout this planning, the need to constantly improve the description of real-time errors associated with HF radar-derived velocity, wind, and wave estimates has been considered.  CIMT researchers have been investigating the error characteristics of HF radar-derived velocity maps by comparing remotely sensed data with in situ data.  Results from extensive, recent comparisons are reported by Paduan et al. (2005).  At the same time, work has continued with circulation modeling partners at the Naval Research Laboratory and the Jet Propulsion Laboratory to test data assimilation schemes for surface velocity mapping data, such as the preliminary method and results described by Paduan and Shulman (2004).

**HF Radar-Based Development of Trajectory-Based Products**

The basic capability and product derived from the HF radar network is maps of surface ocean currents each hour out to distances ranging 50 km to 200 km from shore.  This observing system capability has been established for the Monterey Bay area within CIMT and it is being expanded and perpetuated with support from COCMP. In the meantime, CIMT has been focused on increasing the diversity of user products built around the hourly velocity observations. Examples of such value-added products can be seen in previous CIMT reports, or via the HF radar links at http://cimt.ucsc.edu, where daily trajectory information is produced from the original vector velocity data. A much more complicated example of a potential management product is shown in Figure 11 below, which presents Lagrangian particle statistics based on the computation of tens of thousands of trajectories in Monterey Bay during June 1999 (Lipphardt et al., 2005). This type of calculation shows residence times of surface particles in the region and how they change in space and time. A systematic application of these calculations could be used, for example, to identify high-risk areas for hazardous material spills or optimal areas for larval retention.

During this period, the capability for computing surface current-based trajectories, both real time and retrospective, has been improved. Working with B. Lipphardt of U. Delaware, we have transitioned his FORTRAN- and IDL-based trajectory codes to MATLAB routines, which are compatible with the real-time system running under CIMT. Going forward, this will allow us to export this technology to other observing groups and to have more researchers and managers working with the growing database of surface currents that we have been collecting. With supplemental funding from the California Department of Fish and Game's office of Oil Spill Prevention and Response (OSPR), we have begun to create a demonstration product that will forecast trajectories out twenty four hours based on observed tidal-period and low-frequency velocities from the HF radar network.

**HF Radar-Based Development, Implementation and Testing of Coastal Wind Field Data Products for Monterey Bay and Surrounding Waters**

The HF radar network is being used to improve over-water wind observations, which, in turn, impact the circulation, nutrient transport and other biologically important processes within the "winds to whales" ecosystem. An MCR-based algorithm for vector wind field retrieval has been tested over a year-long period with average accuracy of ≈ 1.4 m/s and 25° (Drake et al., 2004 & Vesecky, et al.,m 2004). A sample HF-derived wind map is shown in Figure 12. The hardware implementation plan described above will, going forward, allow CIMT participants to further develop the operational wind mapping capabilities. The vision for this work is to provide a surface wind field map over the waters of Monterey Bay and surrounding coastal land using the HF radar data, buoys and shore-based anemometers. The Monterey Bay wind field map would be linked with an existing map over San Francisco Bay and surrounding land to provide a surface wind field map extending from near Pt. Reyes south to Pt. Lobos and eventually Pt. Sur.

Figure 11. Particle statistics for June 1999 showing time (in days) for particles originating at a given location to contact coastline or the open ocean boundary moving backward (left) or forward (left center) in time along with total residence time (right center) and a breakdown of the Lagrangian pathways (right).

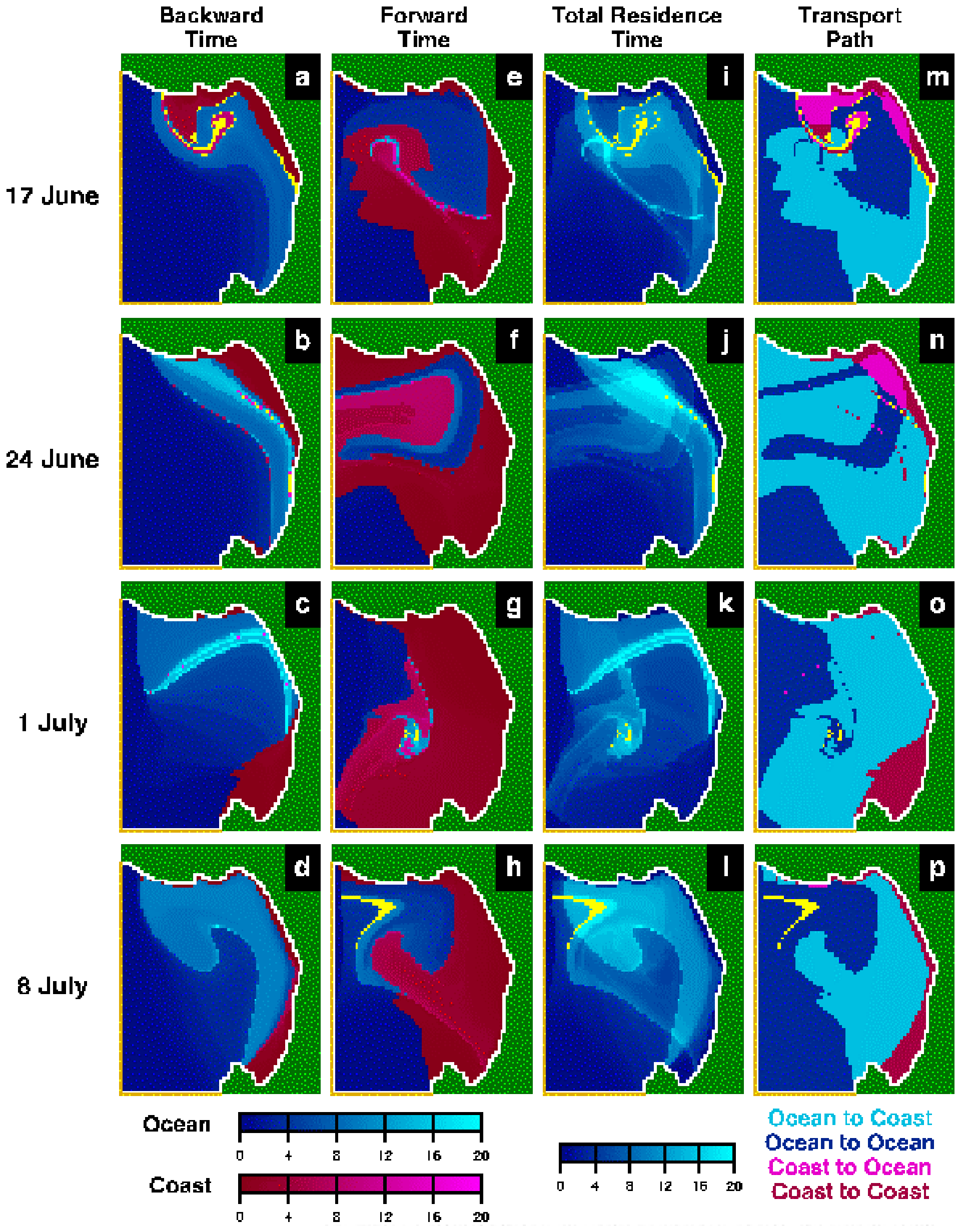
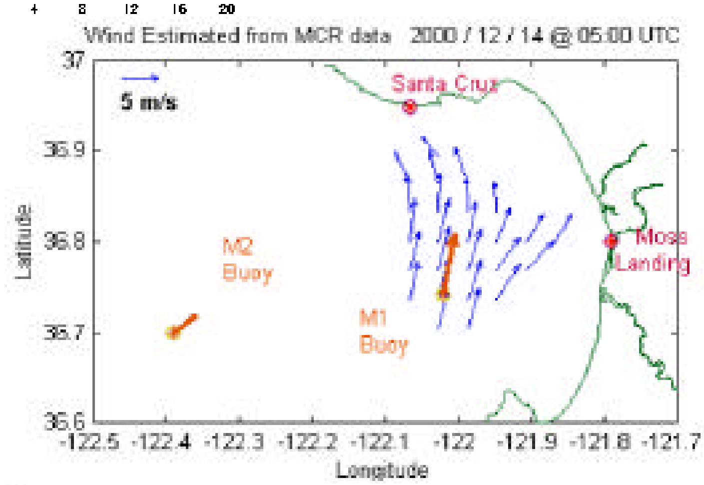



Figure 12. Sample surface wind map from the MCR network (blue arrows) together with observations from the M1 and M2 moored buoys.



## MOORINGS AND OTHER AUTONOMOUS SYSTEMS FOR CIMT

CIMT investigators continued the development and use of autonomous monitoring systems during the first half of the third year of support.

### Development

In collaboration with MBARI engineers working on the MBARI Ocean Observing System (MOOS) a MOOS-Lite Mooring (Figure13) was deployed in Monterey Bay on June 3rd (Figure 14). This marked the first at-sea deployment of a MOOS mooring in support of scientific investigations. The data collected during this deployment is downloaded to the Shore Side Data System (SSDS) via a Software Infrastructure and Applications for MOOS (SIAM) portal (see http://ssdspub.mbari.org:8080/access/cimt.jsp). The system automatically generates and stores the necessary metadata. More recently we have developed software to send a subset of the data in real time to the National Data Buoy Center for use by operational models and the wider public (see http://www.ndbc.noaa.gov/station_page.php?station=46091). In conjunction with David Demer from NOAA SWFC we deployed a Simrad EK60 echosounder on the M1 mooring in October 2004. With MBARI support we continue to investigate the use of moored vertical profilers and autonomous vehicles for future applications.

### Applications

CIMT investigators continue to monitor and process physical oceanographic and meteorological data from the MBARI M0, M1 and M2 moorings (see http://www.mbari.org/oasis/index.html). Staying on top of instrument and data quality-control issues in near real-time is a challenging, and essential, aspect of ocean observing systems.  Through ongoing efforts in this area, we have been able to catch problems within hours, or at most a couple of days.  Of course, weather, ship, personnel, and instrument availability limit how quickly the problems can be solved. These scientific data continue to be widely used by a large number of academic and non-academic institutions in the Monterey Bay area as well as by individuals.

*Scientific Analysis*

Figure 14 shows time series of selected properties collected at the M0 mooring (Figure 15) from deployment in June 2004 until present (February 2005). There are several notable features in the time series: 1) the transition from upwelling/stratification in late summer to deeper mixed layers in the fall and winter; 2) the freshening that starts in late summer and increases in the winter; 3) the highly variable currents; 4) the strong absorption of atmospheric carbon dioxide and associated production of oxygen in the late summer; and 5) the two very large blooms of phytoplankton in the late summer/early fall. The first of these blooms was associated with a period of unusual freshening at the M0. During the bloom there was a particular clear day and satellite imagery (Figure 15) showed cold upwelled water at the mouth of Monterey Bay and a strong increasing gradient in sea surface temperature in to shore. The M0 mooring was in the region of strongest temperature gradients and of highest chlorophyll (Figure 15). Fortuitously an AUV survey took place during the same day (Figure 16). The AUV showed a blob of fresher water sitting just under the coldest and lowest chlorophyll surface water. We hypothesize this cold and fresh water, advected into Monterey Bay as a result of upwelling, made its way to the

M0 mooring and triggered the bloom. The AUV also suggests that even higher levels of chlorophyll were a few meters deeper. The presence of a benthic nepheloid layer in the north bay but not in the south is worth noting.

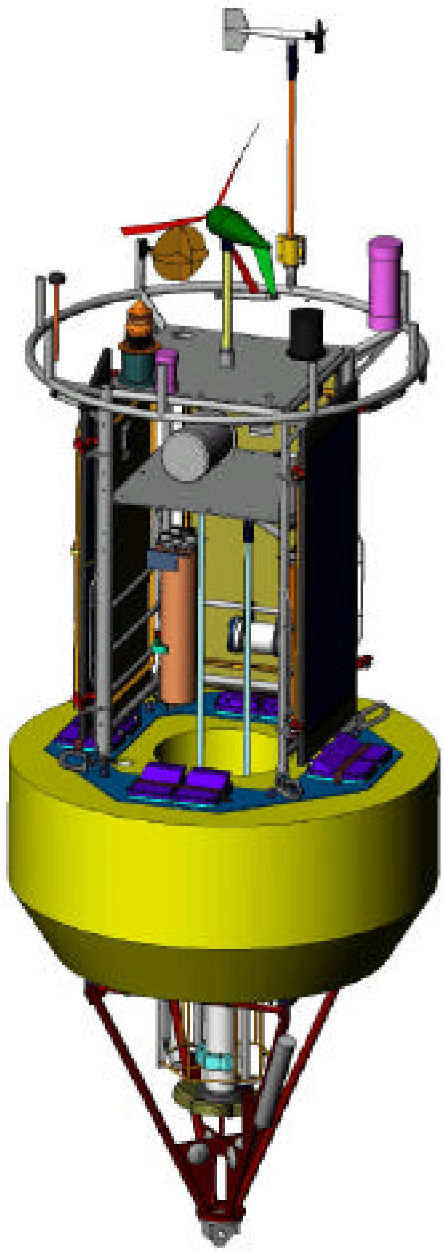


Figure 13. Schematic of MOOS-Lite mooring deployed in Monterey Bay with support from CIMT.

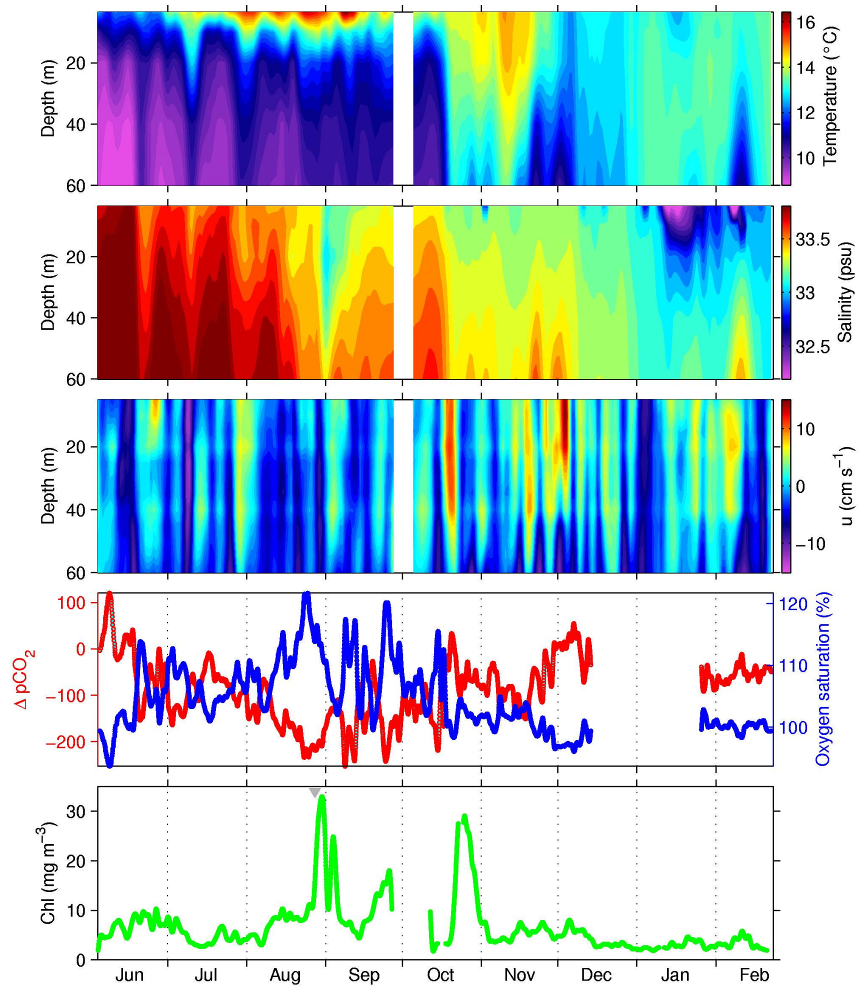



Figure 14. Time series of temperature, salinity, east-west currents, delta partial pressure of carbon dioxide and surface oxygen saturation, and surface chlorophyll at the M0 site from deployment in early June 2004 to February, 2005. The inverted gray triangle at the top of the chlorophyll time series denotes the day when satellite images (Figure 3; also shows the location of M0) and an autonomous underwater vehicle (AUV) section were collected (Figure 4).

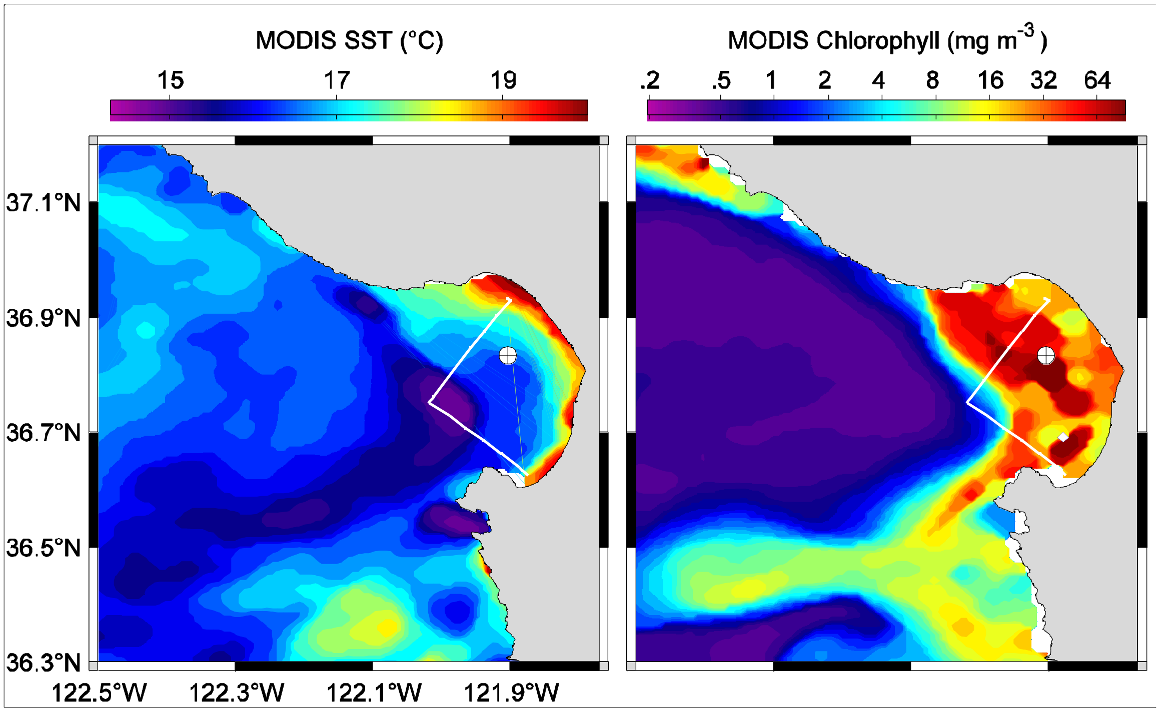



Figure 15. Satellite images of sea surface temperature (left) and chlorophyll (right) collected from MODIS/Aqua on August 27th 2004. Shown are the position of the M0/CIMT mooring (circle with cross) and an autonomous underwater vehicle (AUV) survey (white line) collected on the same day as the satellite images (Figure 16).

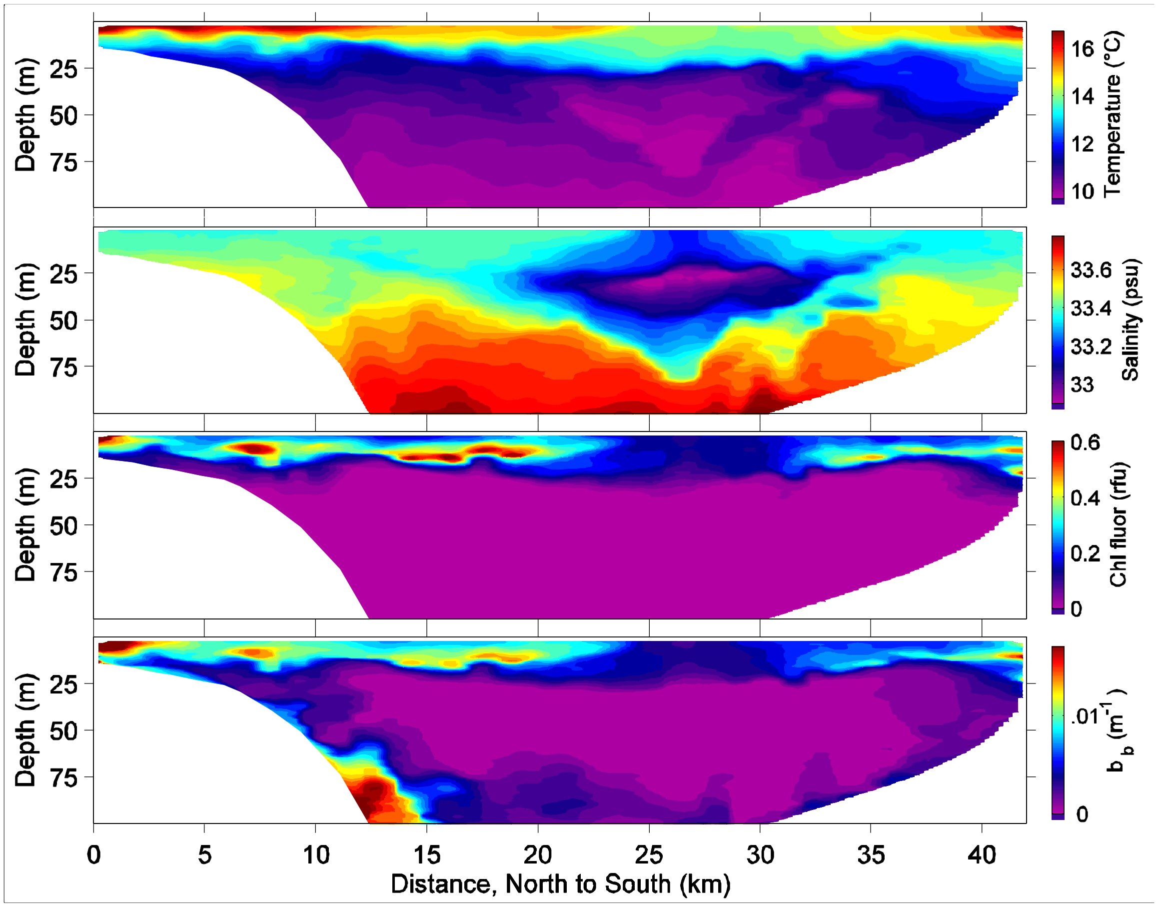



Figure 16. Sections of temperature, salinity, chlorophyll fluorescence and backscatter (see Figure 15) collected with an AUV that was launched off Santa Cruz (left) and recovered off Monterey (right).

## OUTREACH GROUP

### Introduction

The outreach group became part of CIMT in the latter half of Year 2. The goal of CIMT outreach is to develop strong linkages between the CIMT researchers and product end users by improving upon the dissemination of data sets and the creation of effective research and education tools.

The benefits of CIMT's outreach component include providing the bridge between CIMT scientists and CIMT's end users. The outreach coordinator helps identify the best mode of dissemination of CIMT information based on relationships built with end users. The coordinator is the central sounding board for CIMT centric activities or is delegated to participate in meetings, host visitors, prepare comments, and reviewing documents. Having a central outreach component is crucial to maintaining communications between and across CIMT participants to produce products and materials.

There are four major components that make up outreach within CIMT:

- End users,
- Coordination,
- Collaborations and gap analysis, and
- Development of outreach tools

**Progress to Date**

*End Users*
The outreach group will work to ensure that end users are familiar with CIMT products and that they provide critical feedback to the CIMT researchers. To accomplish this, CIMT's outreach and database staff are working together closely with CIMT's principal investigators as they develop visualizations so that products can be provided directly to end user groups, training can be given in product use, and direct feedback can be gained on how products can be improved.

*Accomplishments:*
In preparation for bringing CIMT to end users, the outreach coordinator has formulated an end user strategy through meeting with other outreach specialists from various groups around Monterey Bay including the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO), University of California Santa Cruz (UCSC), California Sea Grant, Monterey Bay National Marine Sanctuary (MBNMS), and the Institute of Marine and Coastal Sciences at Rutgers University. An initial list of potential end user groups has been identified and the coordinator is currently working on contacting these groups. Informational presentations have begun through various regional forums. Two feedback surveys have been developed to use with end users (see section on Development of Outreach Tools).

Examples of some products currently available on the CIMT web site http://cimt.ucsc.edu include:

- *CIMT Cruise Synthesis*, link on Home page and on Research & Monitoring, http://cimt.ucsc.edu/ced_synthesis/index.html the synthesis includes profiles on HF Radar, sea surface temperature, ocean color, wind speed, upwelling wind stress, temperature, density, fluorescence, and salinity.
- *Live Access Server*, link on Data Products page http://borclunn.ucsc.edu:8080/lasCIMT/servlets/dataset?new_output_window=false the server is still currently being modified but has CTD and Echosounder data available for download and/or visualization (please refer to the Database section for further information).
- *Access SSDS (Shore Side Data System) at MBARI*, link on Research & Monitoring page http://ssdspub.mbari.org:8080/access/cimt.jsp this access allows for the download and/or visualization of CIMT data from the MBARI CIMT MOOS Lite Mooring.
- *Access to near-real time satellite data,* link on Research & Monitoring page http://oceandatacenter.ucsc.edu/NRT/ has theS latest and archived imagery for temperature, chlorophyll, winds, HF Radar currents, and wave model.

Some of CIMT end users include the MBNMS staff and SIMoN, the Seymour Marine Discovery Center at Long Marine Laboratory, the California Department of Health Services (CDHS), City of Watsonville, the Central and Northern California Ocean Observation System (CeNCOOS), Point Reyes Bird Observatory (PRBO), Gulf of the Farallones National Marine Sanctuary, Cordell Banks National Marine Sanctuary, Pacific Fisheries Management Council, Pacific States Fisheries Management Commission, Marine Mammal Commission, the National Marine Fisheries Commission, Coastal Ocean Currents Monitoring Program (COCMP), National Marine Fisheries Service, and the California Department of Fish and Game.

The CIMT program has also been shared with a variety of other potential end users, the maritime industry, recreational kayakers and parasailers, the kayak industry, Moss Landing Marine Labs education program, and the Marine Protected Area Center Science Institute. An example includes the Nature Conservancy who hopes to use CIMT data and monitoring efforts in their Central California Ecoregional Planning process during its site specific planning process.

CIMT information has been used on a variety of direct applications, some include:

- Design of monitoring programs, CIMT has been selected as a model on how to sample marine mammals and seabirds for the Sanctuary West Coast Plan and Point Reyes Bird Observatory (PRBO). Working relationships developed with the Channel Islands, Gulf of the Farallones, and Cordell Banks National Marine Sanctuaries and PRBO.
- CDHS Biotoxins Program receives and uses population abundance and toxin analysis information of toxic algal species from CIMT.
- Data models, presentations, reports on food habits of sea lions and pinniped impacts on Salmon stocks.
- Designing of ships including boat structure and appropriate equipment.
- Contributions to development of Sanctuary Management Plan.
- Contributions to educational forums including SIMoN, posters, presentations, and lectures
- COCMP (multi-million dollar state wide program) is replicating CIMT (Monterey Bay) technology.
- Development of "rapid-response" remote sensing products with Dr. Richard Stumpf (NOAA) for the identification of potential HAB problems in California. Information reported directly to CDHS.
- Partnership of CIMT and SIMoN, MBNMS. CIMT data will be used by the MBNMS staff to inform their management decisions and to ensure that the CIMT database and data visualization products are designed to meet the needs of a wide variety of potential end users.
- CIMT continues to participate and contributing to the NOAA IOOS Interoperability Demonstration to create web-accessible maps.
- CIMT is providing local support, dissemination, and validation for remote sensing (ocean color) products in collaboration with NOAA (Dr. Richard Stumpf), Pacific Fisheries Environmental Laboratory (PFEL), and the Tagging of Pacific Pelagics (TOPP) program coordinated by Dr. Barbara Block (Stanford). This partnership includes public access to these data, dissemination to resource managers, and outreach activities (including partnership with the Monterey Bay Aquarium).

*CIMT Coordination*

The outreach coordinator is the central contact for CIMT when group-wide items need to be addressed. Identification and creation of links between CIMT participants that need to occur are formed for successful integration and collaboration. This central hub also assists in the preparation of CIMT wide documents and meetings.

*Accomplishments:*
An important task for the outreach component has been to develop a working understanding of the multiple research efforts that are done within CIMT to increase its integrated understanding. The coordinator has been successful in meeting with all those responsible for the multiple components of CIMT. The coordinator participates in ship surveys and other lab activities as needed. Specific to the ship surveys, outreach work has been successful through the collection of video footage and still photos for outreach products such as a film/animation that will be placed in the Seymour Marine Discovery Center in Santa Cruz and be used in future outreach products (see Development of Outreach Tools for more). In addition the deployment of the CIMT mooring was followed with video, photos and a MBARI/CIMT web article. One mode that has been developed to streamline communication needs about outreach within CIMT is the creation of an electronic *Outreach Update* produced monthly (example at http://cimt.ucsc.edu/cimt_dec_2004.htm). There are goals for a similar publication to be produced for public release in the coming year.

Lessons and needs from end users are being shared with principle investigators to develop future visualization products. To accomplish this meetings occur with the CIMT database manager and participation in a number of visualization development meetings, emails, and conference calls occur on a regular basis. Two project examples follow:

*Project One*: The Outreach Coordinator has regularly been attending the MBNMS Research meetings, and has also been meeting with SIMoN staff at regular bi-monthly meetings. A proposal between SIMoN and CIMT has been initiated. One goal of SIMoN is to be a center for gathering and integrating summary data in an effort to effectively disseminate information to a broad audience. A key component of CIMT is the development of the hardware and software technology for a central web-based portal for data visualization, access, and interpretation. The proposal is an effort to identify the areas of overlap and complementary outreach in progress at CIMT and SIMoN and to ensure that the CIMT database and data visualization products are designed to meet the needs of a wide variety of potential end users. It has been proposed to jointly develop a pilot project that will build a geographic information system (GIS) and static data visualization products for use by both CIMT and SIMoN. Draft products from this proposal include a GIS of backscatter (Figure 17), marine mammal and seabird observation, and one of sea surface temperature. These visualizations have been distributed throughout the MBNMS staff to identify any improvements. Feedback has been provided to CIMT GIS staff and improvements are being made prior to publication on the CIMT web site.

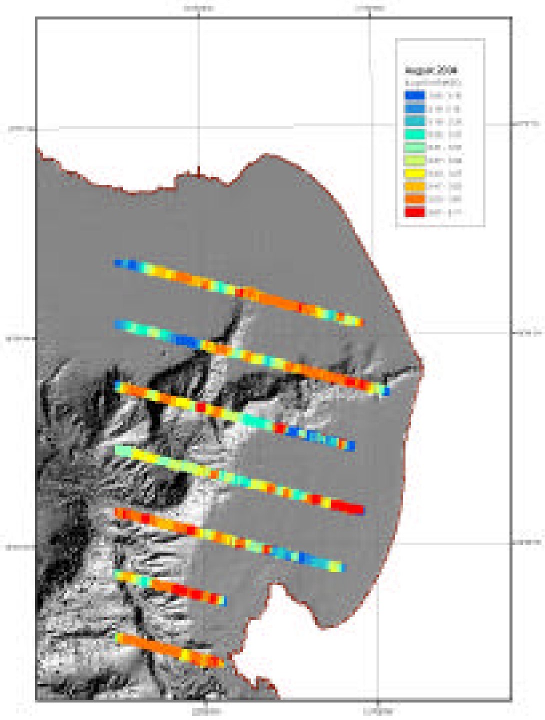


Figure 17: Zooplankton backscatter for the August 2004 CIMT ship survey.

*Project Two*: The Coordinator was approached at The Central Coast Joint Data Committee GIS Day 2004 (November 19th) by a recreationalist kayaker and parasailer about providing wind direction and speed data. The Coordinator met with other marine recreational users and after presenting the need to CIMT through the Outreach Update (December 2004) Dr.'s Rosenfeld and Chao stepped forward to begin product design for marine recreational users. This project is still in the technical development phase. Stakeholder needs from other marine recreational groups are being considered for the final product as needs continue to be identified. This is a dynamic process and the product will be adjusted to suite CIMT end user needs.

**Collaboration and Gap Analysis**

CIMT collaborations occurs at a variety of levels that have been mentioned throughout this report, including Chris Clark and the Bioacoustics Lab of Cornell University, PFEL, and Dr. Rick Stumpf of NOAA to name a few. Specifically the outreach component is building collaborations with the Seymour Marine Discovery Center, MBNMS, SIMoN, Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO), Tagging of Pacific Pelagics (TOPP), Center for Integrative Coastal Observation, Research and Education (CI-CORE) and CeNCOOS.

It is also the responsibility of the outreach component to help identify gaps of knowledge that would benefit stakeholders and make CIMT more comprehensive in scope. This identification may be done during the stakeholder process and may initiate further collaborations in the future.

*Accomplishments:*

CIMT is working closely with our developing regional Integrated Ocean Observation System (IOOS) the CeNCOOS. The CIMT Outreach Coordinator is also the chair of the End User Committee for CeNCOOS and direct coordination is planned with any guidelines developed by the IOOS Education Steering Committee. The Coordinator volunteered to run the dialogue section of CeNCOOS organizational meeting (June 1, 2004), provided text and layout design for a collaborative CeNCOOS fact sheet "Ocean Observing Making a Difference in Central and Northern California", and corresponds regularly through meetings, phone, or email with Stephanie Watson. At least one CIMT member sits on each of the five CeNCOOS committees, Interim Executive (G. Griggs), End Users (R. Robison), Data Management and Communications (J. King), Science (F. Chavez, R. Kudela, J. Paduan, L. Rosenfeld), and Governance and Business Plan Development (L. Rosenfeld, J. Paduan) committees. Many CIMT members participate in CeNCOOS organizational meetings and provide review of CeNCOOS materials.

In addition to working with CeNCOOS working relationships have been formulated with other monitoring groups including CICORE and the PISCO to address the end users and their needs in our area. A joint process for reviewing existing documents that identifies end users and their needs has begun. This process was formulated out of a CeNCOOS' end user committee meeting.

The Seymour Marine Discovery Center has been a huge supporter of CIMT. Our collaboration with them focuses on bringing CIMT data to the general public, such as teachers and K-12 students. Some of our outreach tools are being developed through direct feedback from the Seymour Marine Discovery Center staff and volunteers. Future collaborations with this group include development of a lecture series on ocean monitoring, educational curriculum, and ocean monitoring exhibit.

*Development of Outreach Tools*
The creation of a variety of outreach materials is necessary to communicate CIMT to a broad audience. Outreach tools include brochures or fact sheets, posters for forums, post cruise summaries, pictures, web site development, following deployments or highlighting new research with video or press releases, and helping in the technical design of animations and visualizations.

*Accomplishments:*
*1) Film/Animation & Still Image:* The Coordinator has been working with Jesse Hiatt Studios toward the completion of introductory film/animation and still image on CIMT. The film will initially be used by the CIMT coordinator to educate end users in a variety of venues on CIMT and be displayed in the entrance exhibit at Seymour Marine Discovery Center in Santa Cruz, California. The film has already undergone a first and second draft release which has been shown to the Visitor Program Manager and Director of the Seymour Marine Discovery Center at Long Marine Laboratory for feedback. The film is currently undergoing final edits to make sure that it meets the needs of the general audience. The Coordinator has used the draft film successfully at the recent GIS day event held by the Central Coast Joint Data Committee (November 2004). A CIMT still image has been drafted and going through final revisions. This still will provide one view of the complex monitoring that is being preformed by CIMT in Monterey Bay.

*2) Website:* Work has been contracted with Dr. Dale Robinson to update the design and content of the CIMT website http://cimt.ucsc.edu. CIMT's long and short term goals and lists of desirables for the website have been provided to Robinson for incorporation to the redesign of the CIMT website. A scope of work has been received and the initial architecture has been designed. Robinson has also worked on the development of the CeNCOOS and the CICORE websites. The goal is that an effort on the part of marine monitoring projects in the Monterey Bay area to be consistent on as many areas of outreach as possible will improve the understanding of ocean observing systems as a whole. Once the re-design is complete the coordinator will meet with SIMoN and CIMT technical staff to present the needs of stakeholders and to work with technical staff to maintain the most effective web design.

*3) Printable Materials:* Work has been done on initial drafts of outreach products. Specifically a CIMT fact sheet has been completed and distribution has been successful. Through the participation in ship surveys post-cruise summaries are beginning to be compiled that will allow the end users to follow the work that CIMT has been accomplishing, available on the website. In addition CIMT specific outreach products have been drafted including a general information poster and presentations.

*4) Surveys:* Collecting stakeholder needs on the prospective uses of CIMT data is crucial to making CIMT operational. To further this process, two brief surveys have been prepared by using existing surveys done by SCCOOS (Southern California Coastal Ocean Observing System) and MBNMS. Each survey addresses a separate information need. One survey addresses end user needs and the second asks for feedback on the effectiveness of the web site (http://cimt.ucsc.edu). Both surveys will be available online and the end user survey will be available for distribution. The end user survey has been sent out for review and will be directly linked through the web site in March 2005.

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